Quarkonia Studies in PbPb Collisions by the ATLAS Experiment at LHC

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Why Quarkonia?

Quarkonium dissociation due to color screening is considered as a promising signature of QGP formation.

Different quarkonia states are expected to "melt" at different temperatures.

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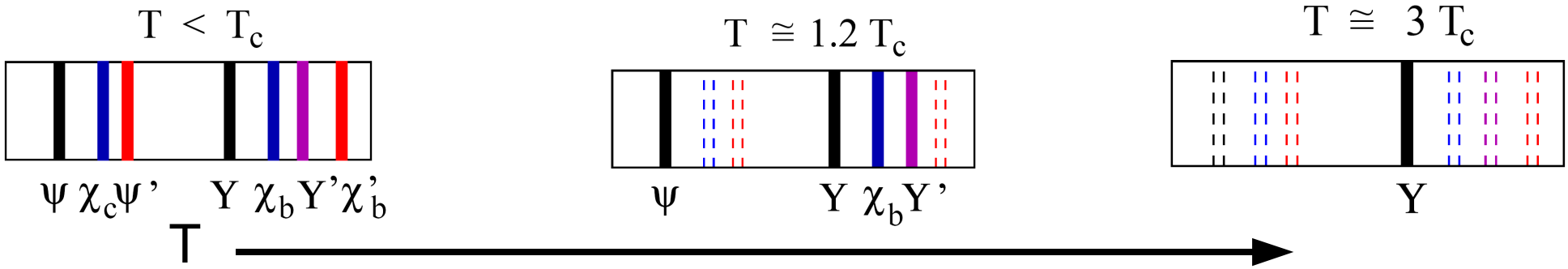


Recent RHIC results point to importance of recombination of quarkonia in the later stages of the collisions.

Also need to consider feed-down from higher resonances

Complicated picture:

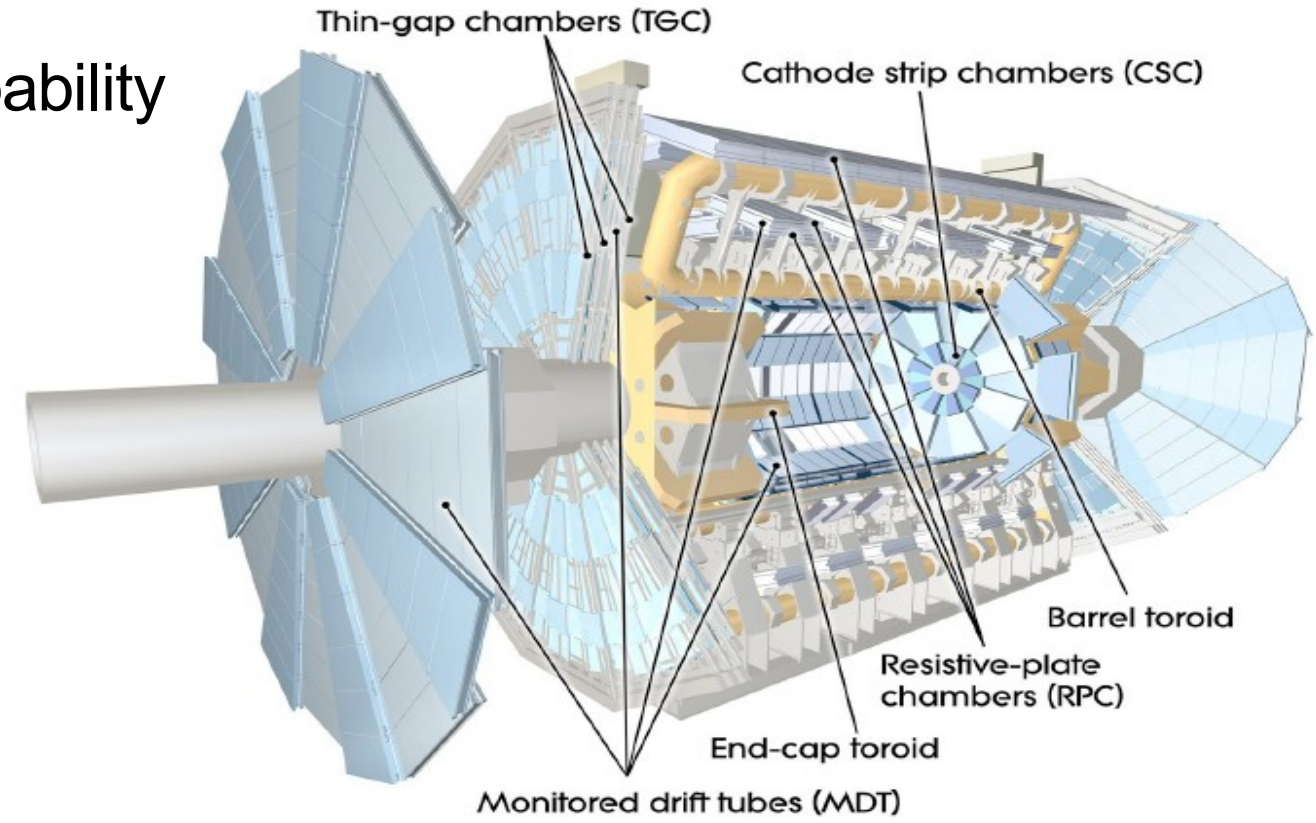
It is important to measure simultaneously different quarkonia states in order to understand heavy ion collisions

The ATLAS Muon Spectrometer

ATLAS has excellent capability to identify quarkonia in di-muon channel

Toroidal magnetic field created by 3 magnets (barrel and 2 endcaps)

Air-core coils to minimize the multiple scattering



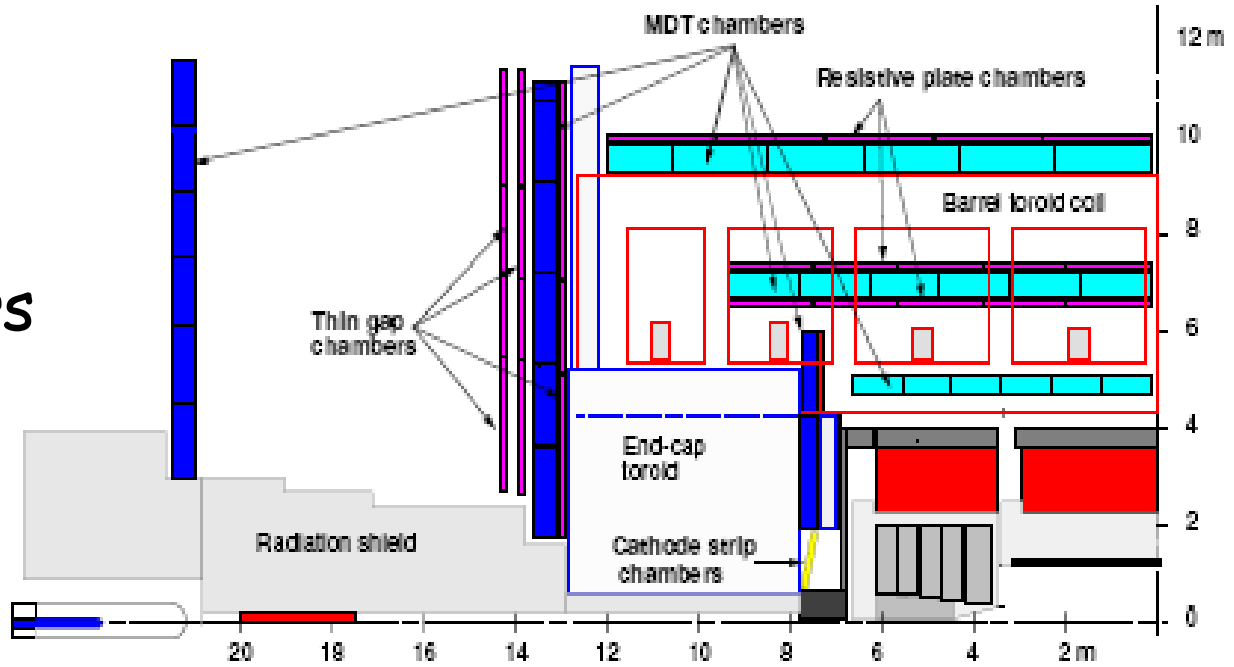
Three layers (stations) in the barrel ($|\eta|<1$),
Four disks in the endcaps (up to $\eta \sim 2.7$)

The ATLAS Muon Spectrometer Details

Muon Chambers

Trigger chambers

- Resistive Plate Chambers in barrel (RPC)
- Thin Gap Chambers in the endcaps (TGC)



Momentum measurement chambers

- Monitored Drift Tubes (MDT) in most of the acceptance
- Cathode Strip Chambers (CSC) in most forward region

Provide high P_T resolution ~5% at 10 GeV/c

Coverage: $|\eta|<2.7$; $P_T > 2.5$-3.0 GeV

Muon Reconstruction in ATLAS

Muon standalone algorithms

- Muon tracks are reconstructed using Muon Spectrometer only

Combined algorithms use information from the Muon Spectrometer and the Inner Tracker (silicon pixels and microstrips)

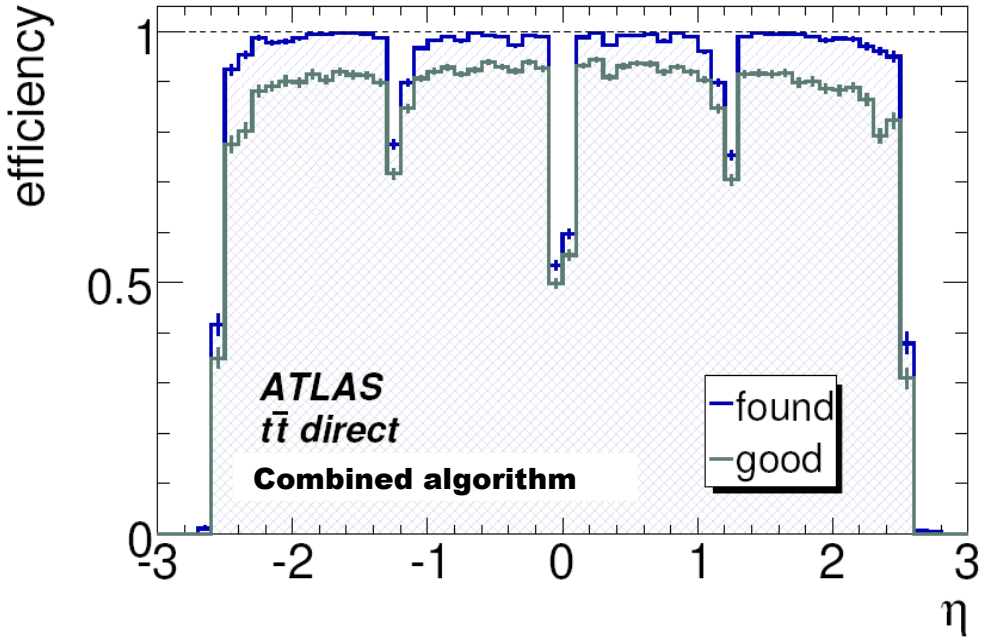
- Muons are found by matching standalone muons to inner tracks and then combining the measurements from two systems.

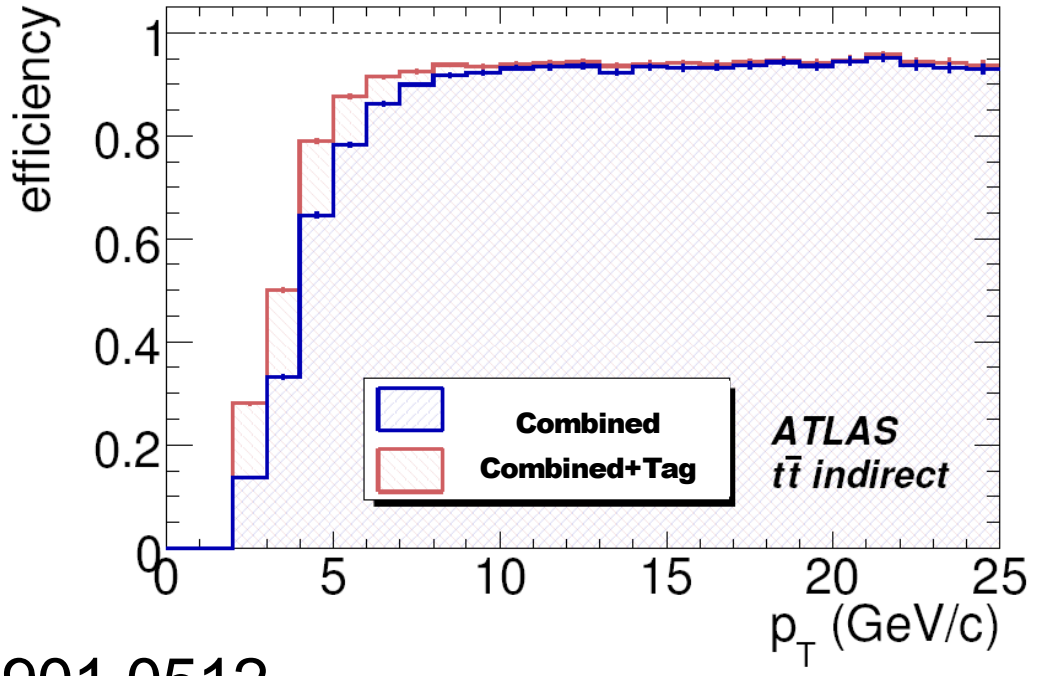
Tagging algorithms (low P_T)

- Inner tracks are identified as muons if they match unused muon track segments in the first muon station.

Muon Spectrometer Performance in p+p

- Reconstruction efficiency is >90% for P_T > 6 GeV
- Muon momentum resolution ~5% at 10 GeV
- Wide η coverage.



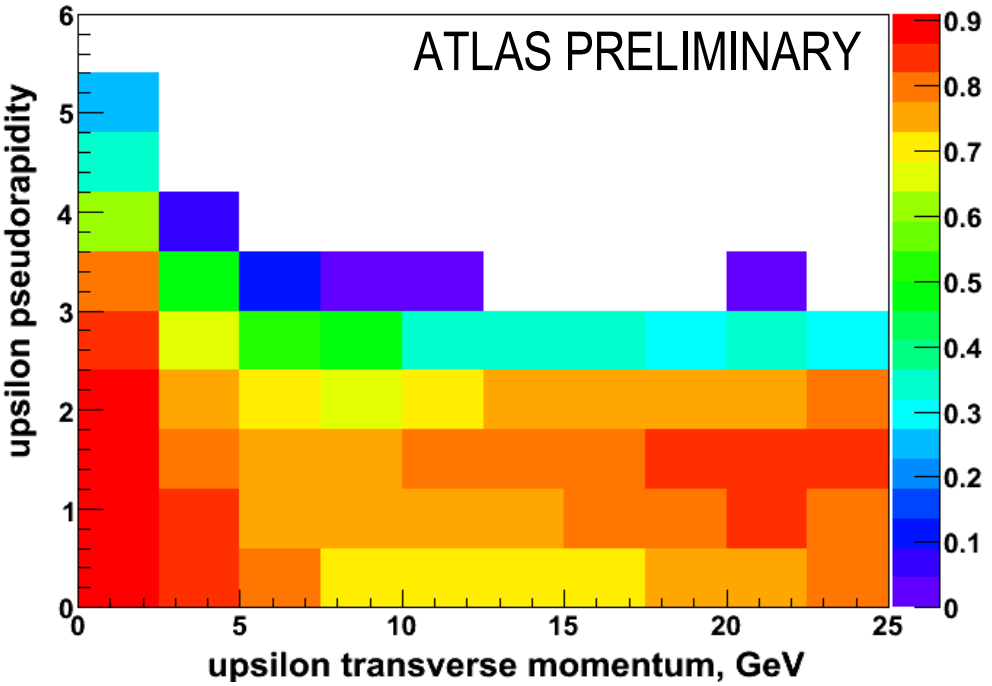


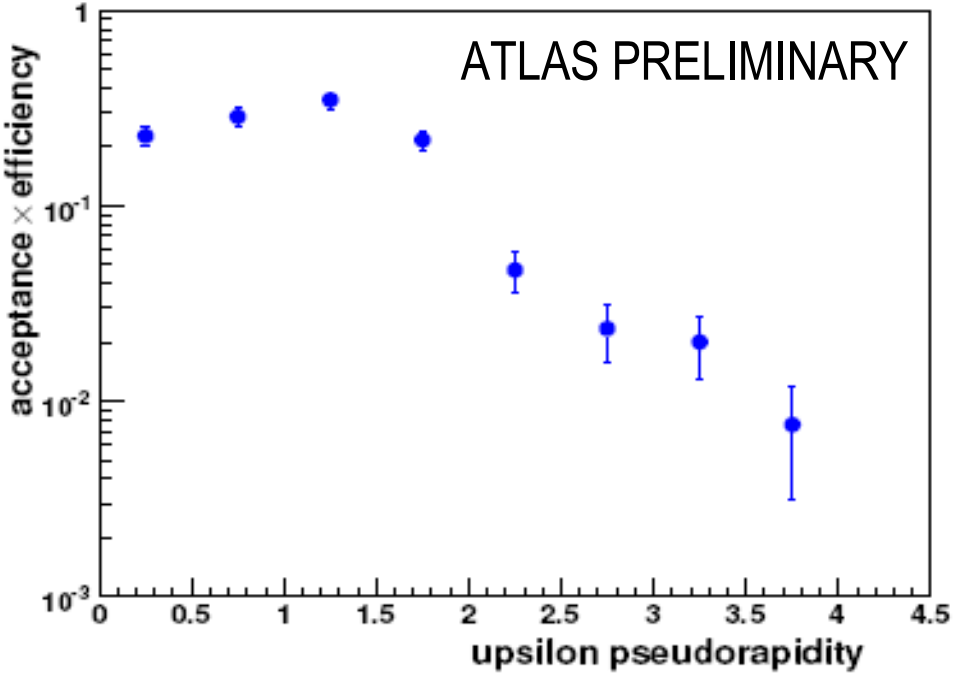
arXiv:0901.0512

Upsilons in Pb+Pb Events

ATLAS ability to measure quarkonia in Pb+Pb collisions at 5.5 TEV was studied by merging single quarkonia to minimum bias Hijing Pb+Pb events and running full reconstruction chain.

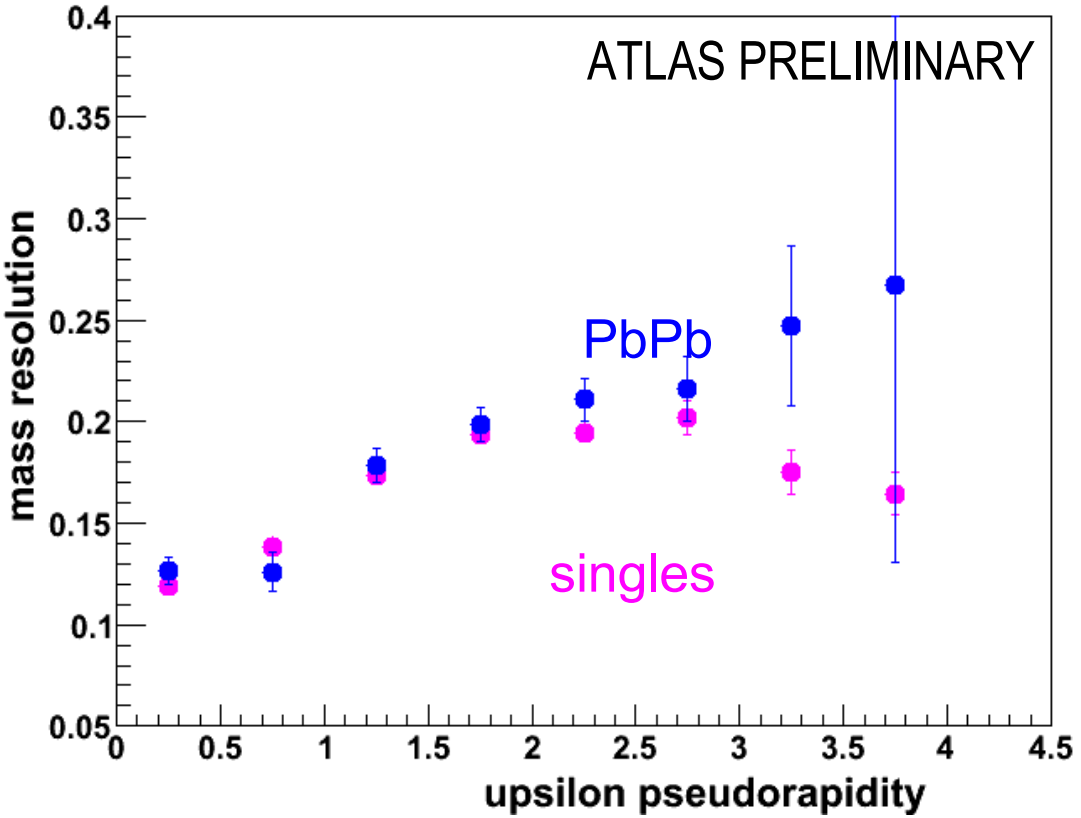
- singles had flat distribution in P_T and η, weights from PYTHIA were used to fill histograms.



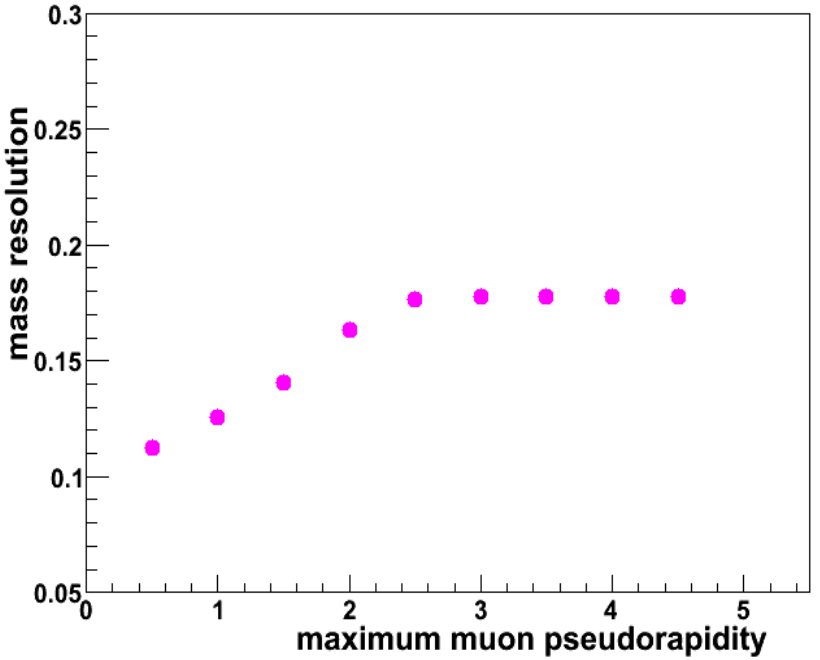


Upsilon Mass Resolution (Pb+Pb)

- Integrated (over P_T and η) mass resolution is ~190 MeV
- Mass resolution for $|\eta_\Upsilon|<1$ = 120 MeV
- Best mass resolution (both muons in barrel) = 112 MeV
- Mass resolution is unaffected by high multiplicity



Improving mass resolution by restricting muon eta



Background and Yields (1/2)

Assume that both high pT muons and Υ scale with number of binary collisions. Then background will scale as a square of signal, and S/sqrt(B) ratio will be the same for pp and PbPb.

Sources of background:

a) open charm and beauty

- use pythia to get muons from charm/beauty

b) hadron decays (mostly π & K) and hadron punch-through

- generate single pions and kaons, run full simulation, plot reconstructed muon spectrum

Add Upsilons to this mix.

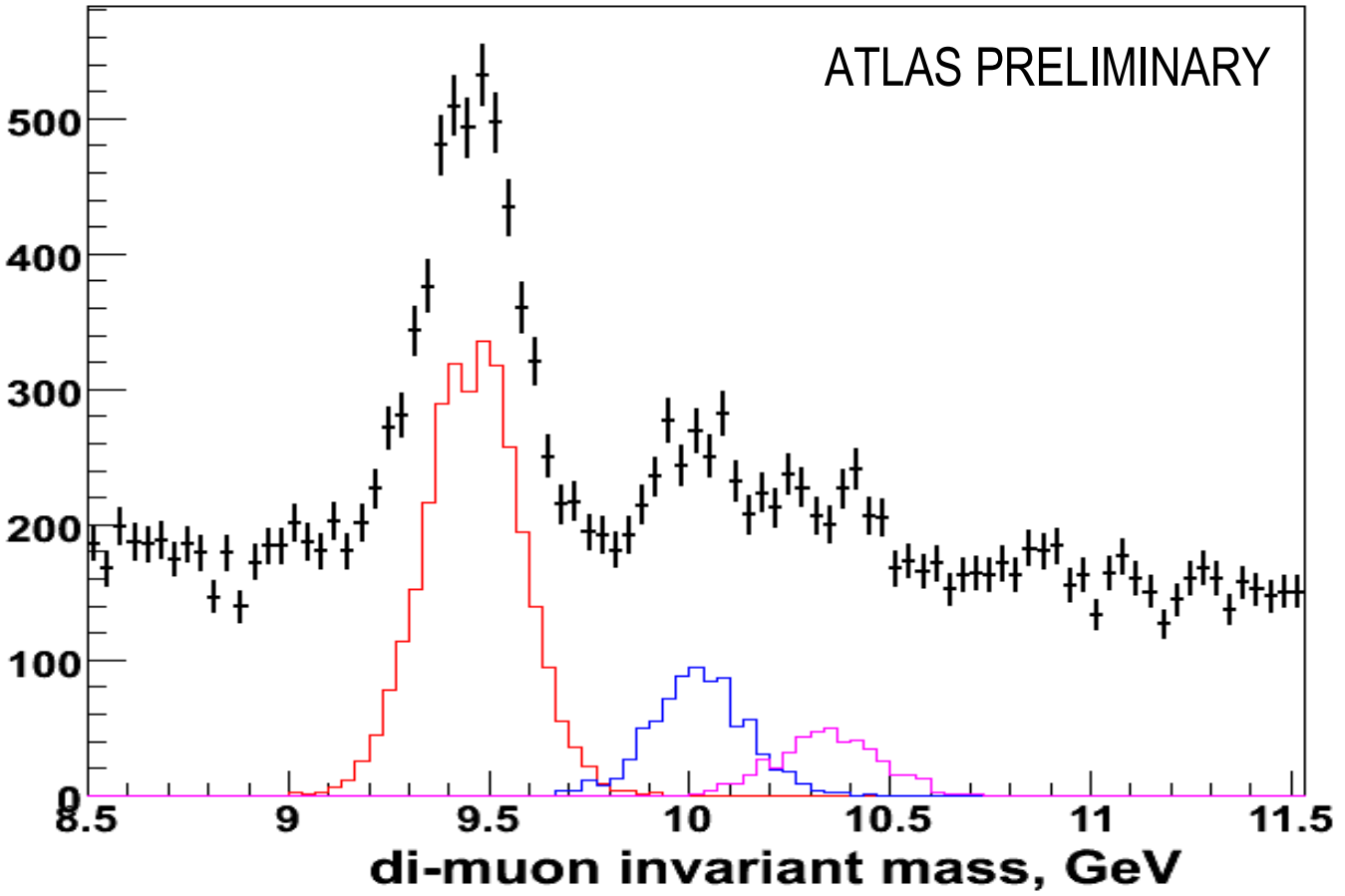
Scale everything with number of binary collisions:
400 (MB); 1670 (central) (*David d'Enterria, nucl-ex/0302016*):

Run MC simulation and produce di-muon invariant mass spectra.

Background and Yields (2/2)

Plot for one month of running at nominal luminosity with 50% LHC+ATLAS efficiency, equivalent to integrated luminosity of 0.5nb-1

Acceptance and efficiency corrected, no trigger efficiency. Barrel only.

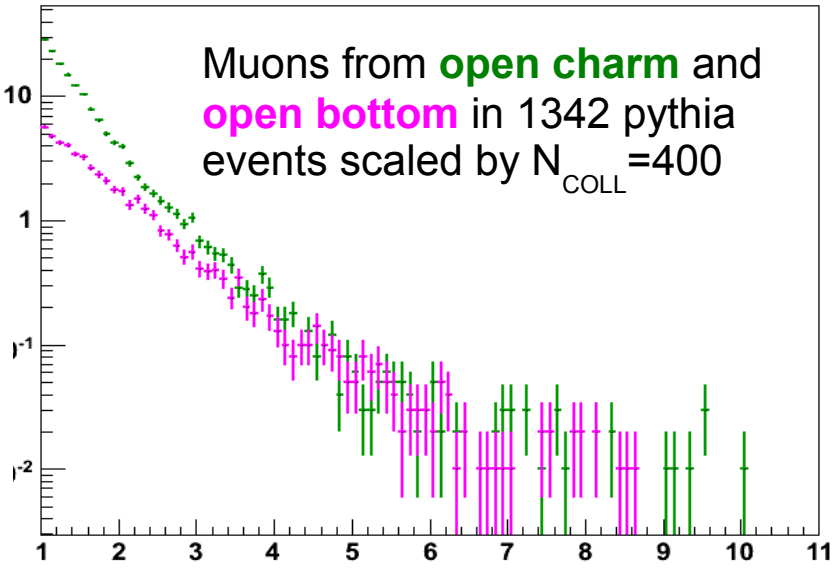


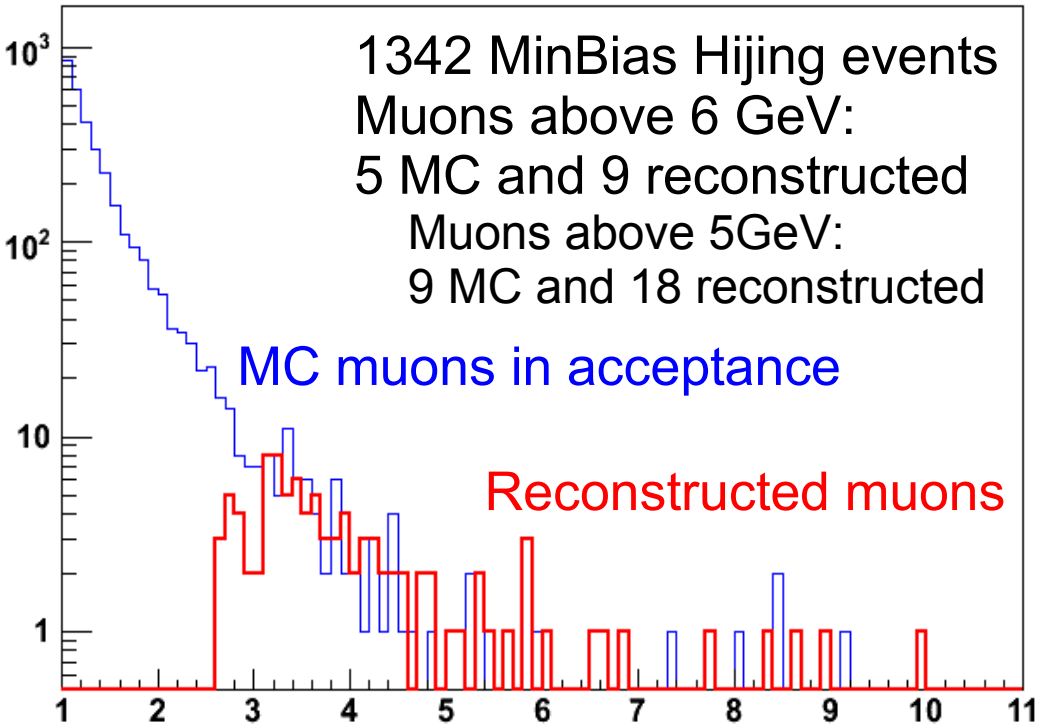
Upsilon Triggering Issues

We may have to use Level-1 trigger to scale down from several thousand Hz collision rate to 50 Hz (or less) to tape.

Sources of high P_T muons:

- hadron decays and punch-throughs
- open charm and bottom





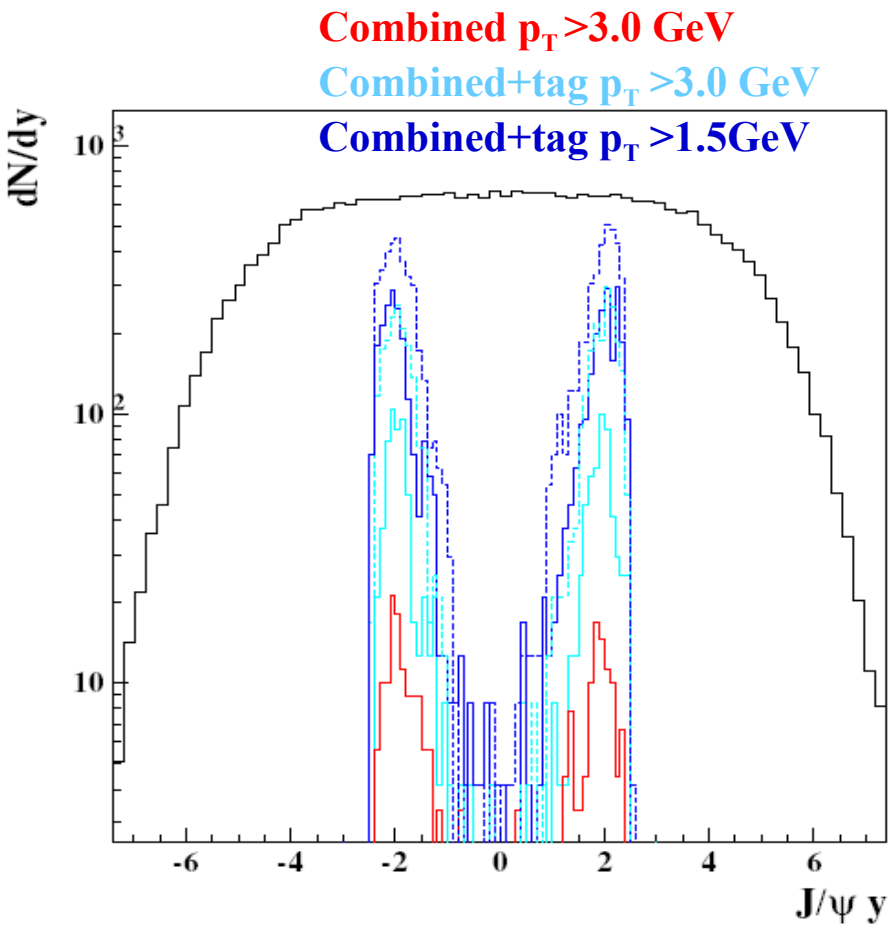
Upsilon triggering efficiency:
L1_MU4: 79%
L1_MU6: 60%
L1_MU10: 26%
(from Upsilons in PYTHIA)

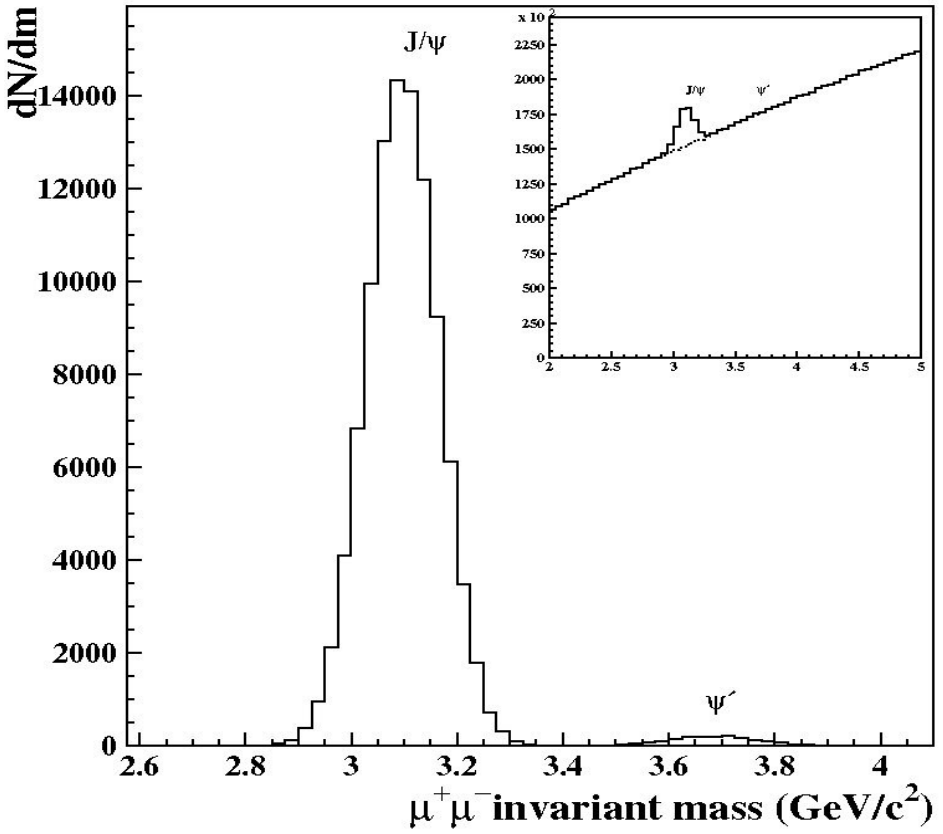
J/ψ Reconstruction in Pb+Pb Events

Main problem: low acceptance due to minimum muon P_T ~2.5-3.0 GeV

Two methods considered:

- both muons fully reconstructed
- "tagging method" for one muon *(allows muon reconstruction down to 1.5GeV).*





Mass resolution 68 MeV; tagging method

Summary of Quarkonia Performance

	J/ψ	Υ	Υ (μ in barrel)
Acceptance x efficiency	0.53%	12.5%	4.7%
Mass resolution (MeV)	68	190	112
Signal/Background	3:20	3:10	4:10
Rate/month	130k	19k	7k

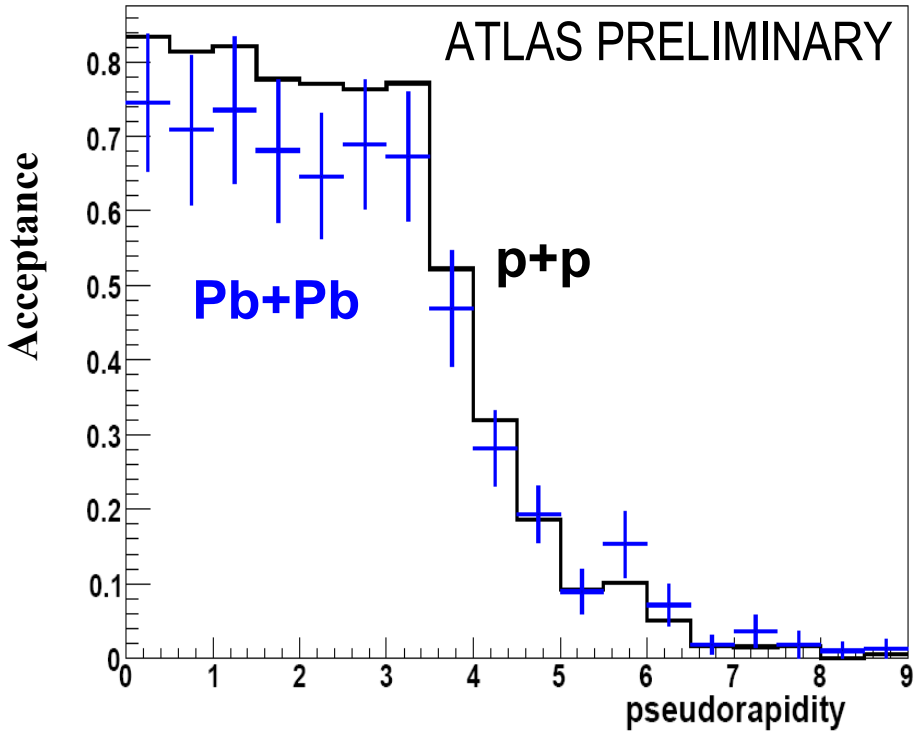
Rates calculated for one month of running at nominal luminosity with 50% LHC+ATLAS efficiency, equivalent to integrated luminosity of 0.5nb-1

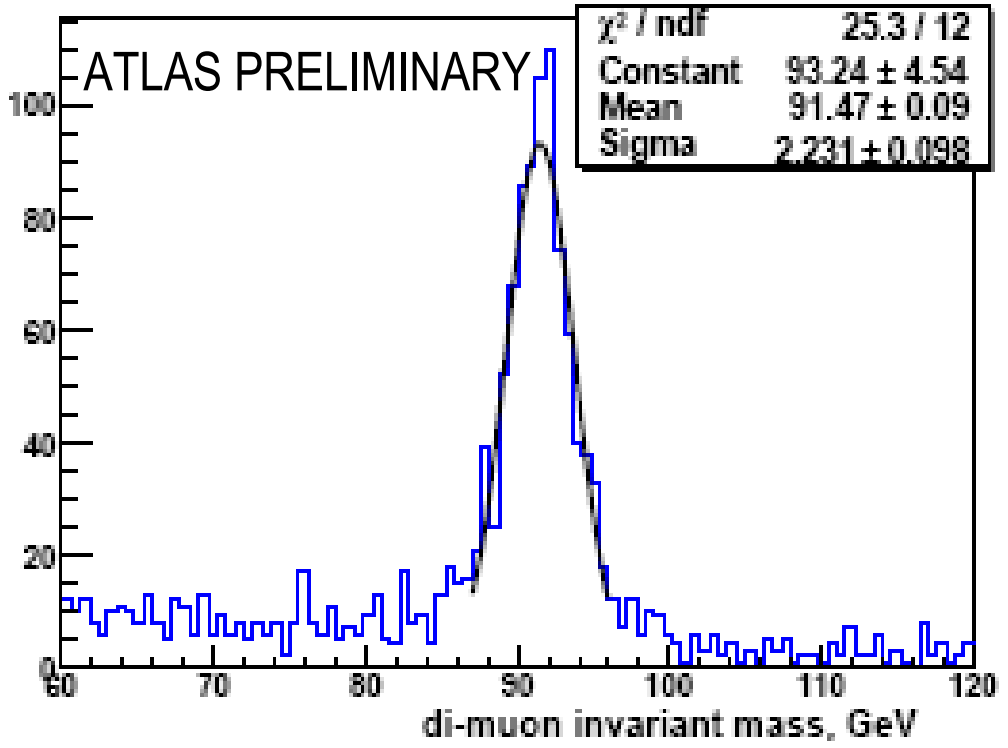
Z^o Bosons

- No pA collisions at LHC
- Use Z to determine "cold nuclear matter" effects

  Z production in p+p can be accurately calculated in pQCD,

  Measuring Z in Pb+Pb will provide information about PDF modification





Acceptance x efficiency ~60%

Mass resolution ~2.2 GeV (almost unchanged in Pb+Pb)

Rate ~8k per month

Conclusions and Outlook

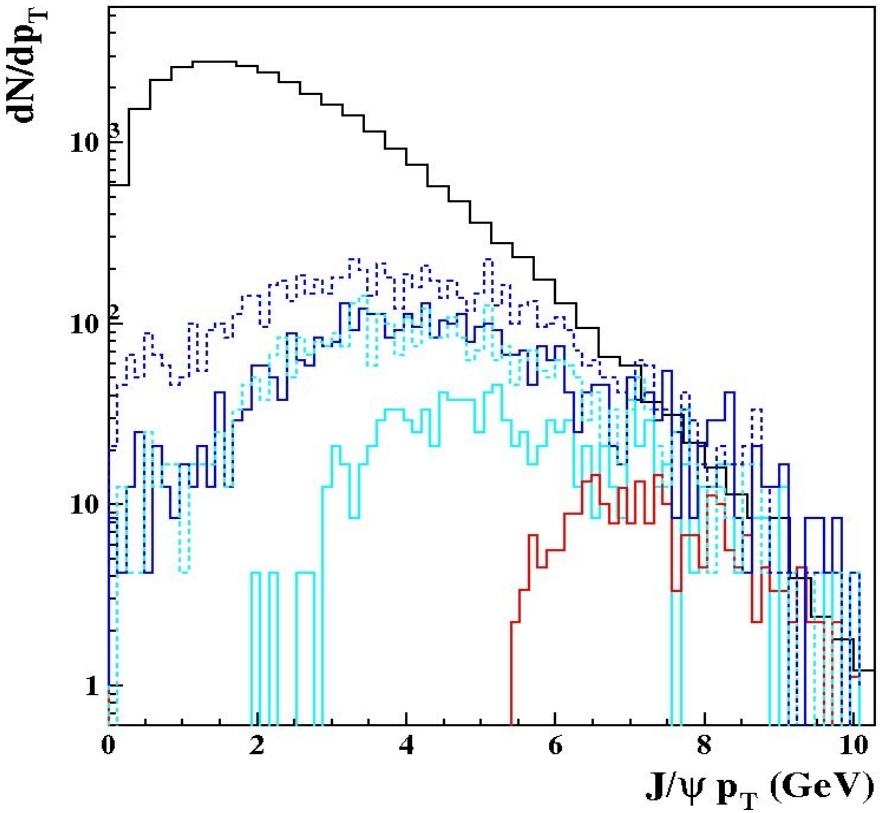
- ATLAS has excellent capability to measure quarkonia in heavy ion collisions at LHC

- Quarkonia mass resolution is almost unaffected by high multiplicity, and good enough to separate 3 Y states

- Should be able to see Y and J/y peaks in few weeks of running

- Feasibility studies of χ_C measurement and quarkonia in e+e- channel are underway

Backup slides


dN/dp_T
10^3
10^2
10
1
0
2
4
6
8
10
J/ψ p_T (GeV)

Why Quarkonia?

Quarkonium dissociation due to color screening is considered as a promising signature of QGP formation.

- Different quarkonia states are expected to "melt" at different temperatures.

Recent RHIC results point to importance of recombination of quarkonia in the later stages of the collisions.

- Also need to consider feed-down from higher resonances

Complicated picture:

- It is important to measure simultaneously different quarkonia states in order to understand heavy ion collisions

In this talk we study possibility to measure charmonium (J/ψ) and bottonium (Υ) states via di-muon channel in PbPb collisions by the ATLAS experiment at LHC.

Background and yields (1/3)

Total pp cross-section at 5.5 TeV: ~100mb

bbar cross-section at 5.5 TeV: ~100μb

Υ cross-section: ~100nb

- Upsilon cross-section in pp collisions was studied using pythia:

  http://dprice.web.cern.ch/dprice/work/oniumvalidation-jun06.pdf

- 34nb with default trigger cuts, ~150nb with relaxed trigger cuts.

One Upsilon reconstructed in ~1M pp events

PbPb expected luminosity is 4 10^{26} $cm^{-2}s^{-1}$ (Letter of Intent)

- Interaction rate several thousand Hz

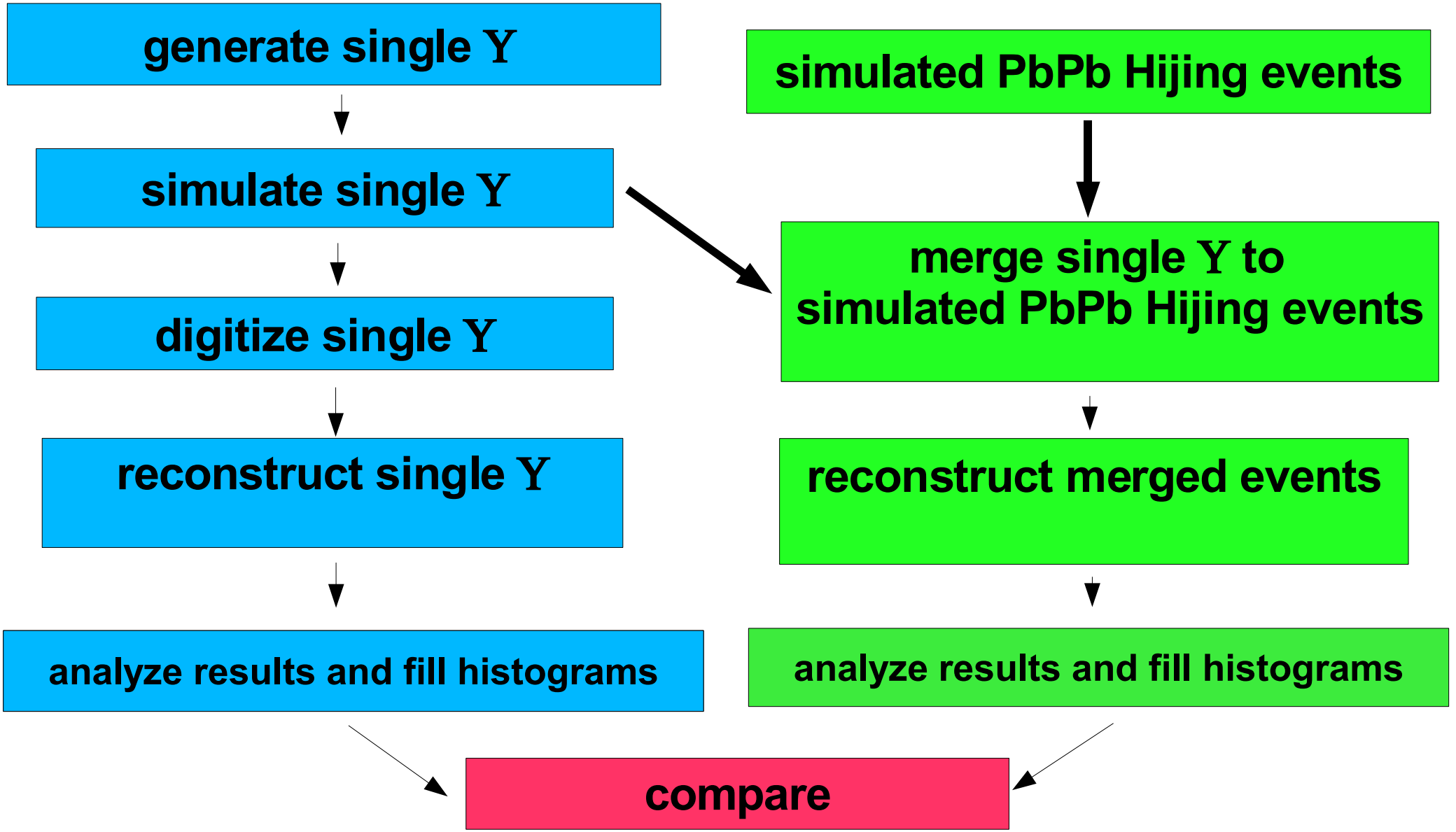
from Glauber calculation (*David d'Enterria, nucl-ex/0302016*):

- Total PbPb cross-section: 7.7b
- Number of binary collisions: 400 (MB); 1670 (central)

Assume that both high pT muons and Υ scale with number of binary collisions. Then background will scale as a square of signal, and S/sqrt(B) ratio will be the same for pp and PbPb.

Heavy Ion Simulation Study

Υ with flat P_T and η distributions, weighted with Pythia distributions.



Conclusions and outlook

- Reconstruction efficiency is reasonably good even in most central PbPb events

- Mass resolution is almost unaffected in PbPb collisions

- Mass resolution is good enough to separate different Υ states at least in the barrel region

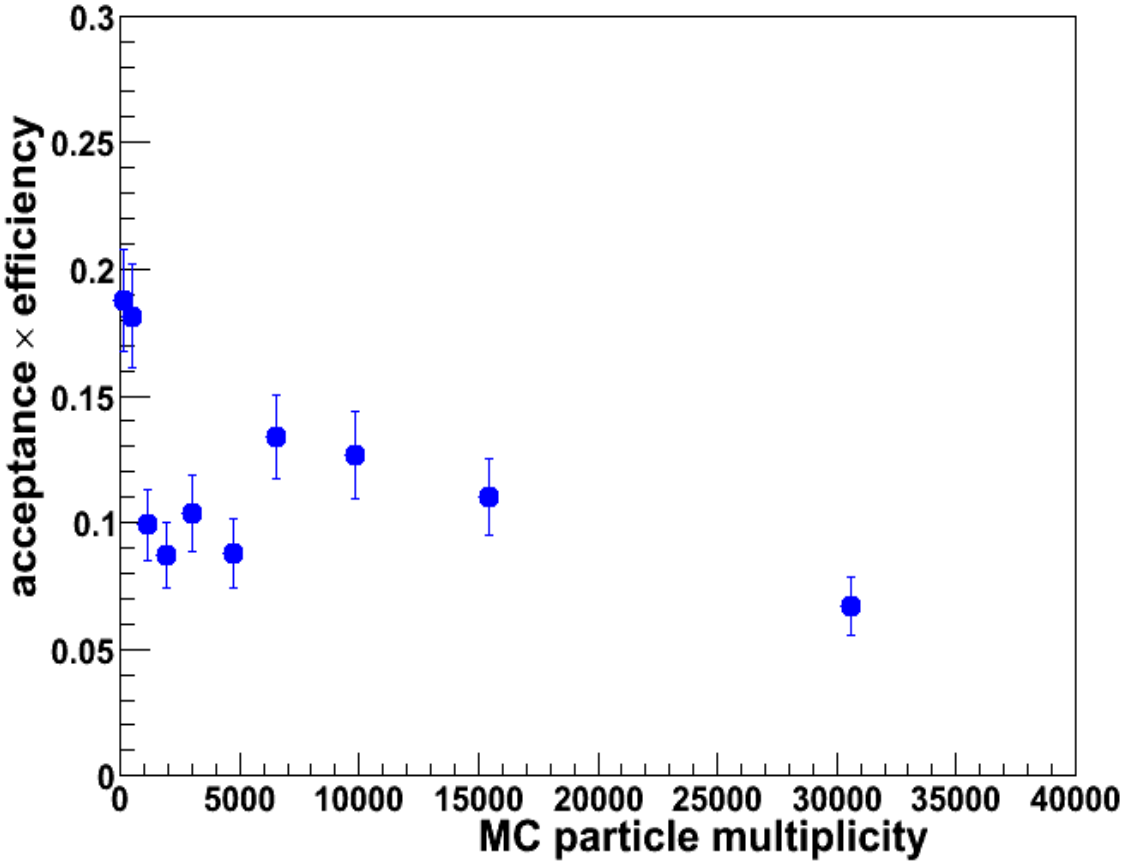
- We should be able to see Υ and J/ψ peaks in a few weeks of running

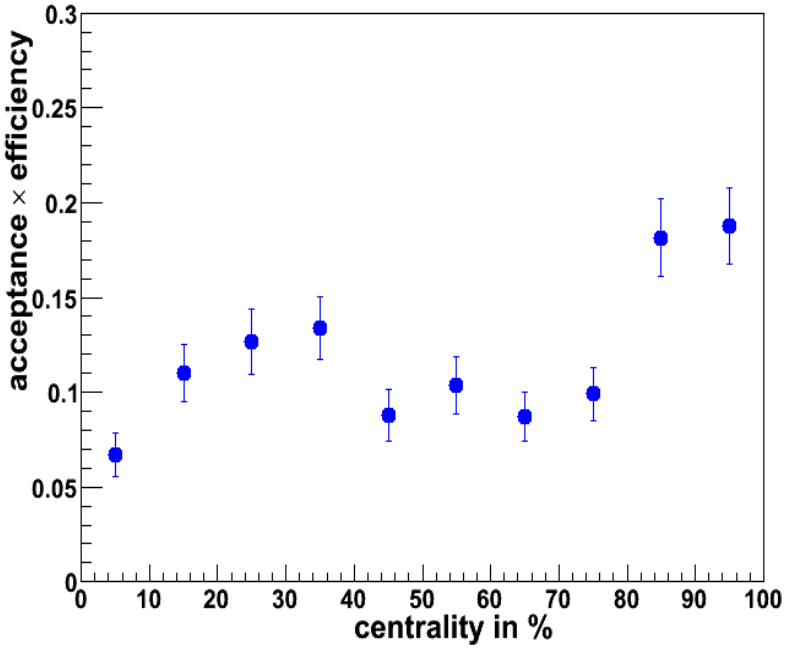
- Quarkonium study in e+e- channel is underway

- χ_C study is underway

Reconstruction efficiency vs centrality

- Integrated (over P_T and η) acceptance times efficiency is 0.12
- Factor of ~2 loss in most central collisions

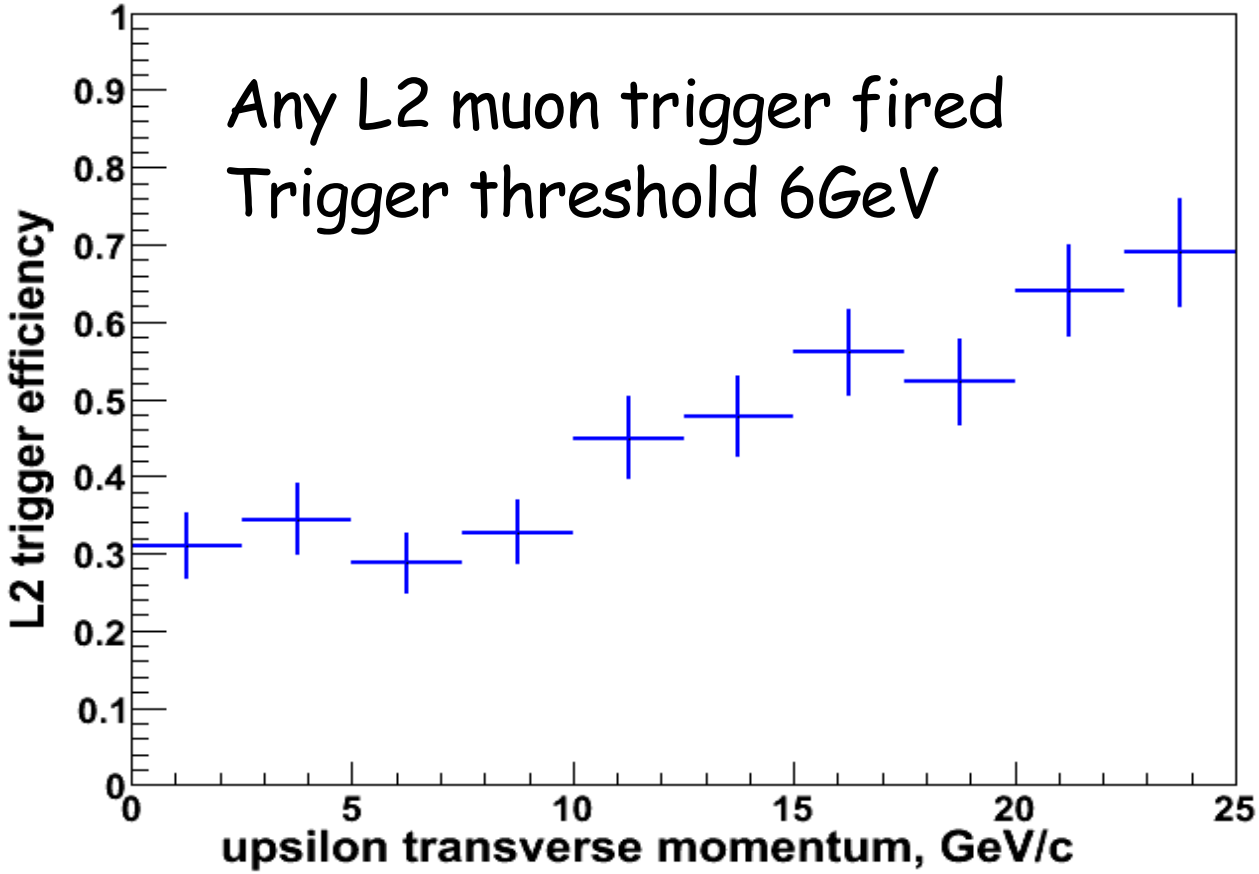




Triggering on Upsilons

efficiency = (Υ reconstructed & muon trigger fired)/(Υ reconstructed)

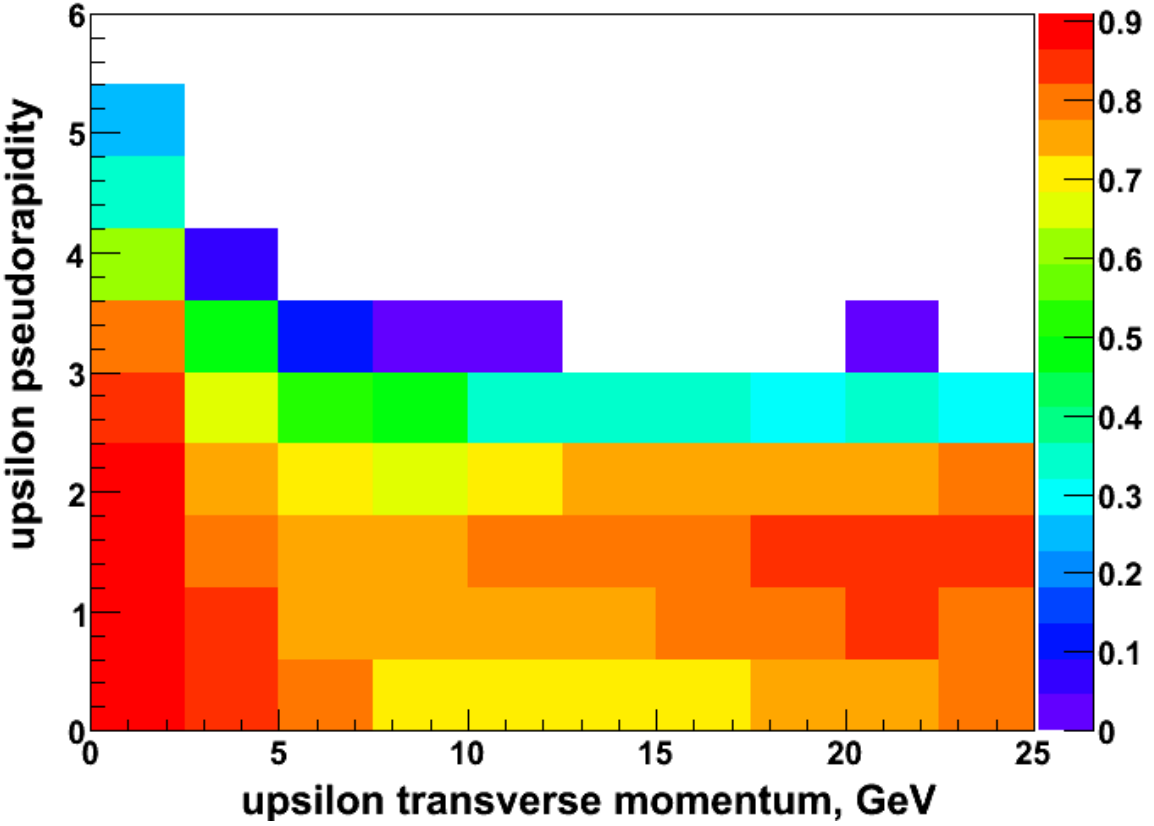
No fakes in ~250 PbPb Min. Bias Hijing events (without Υ merging)

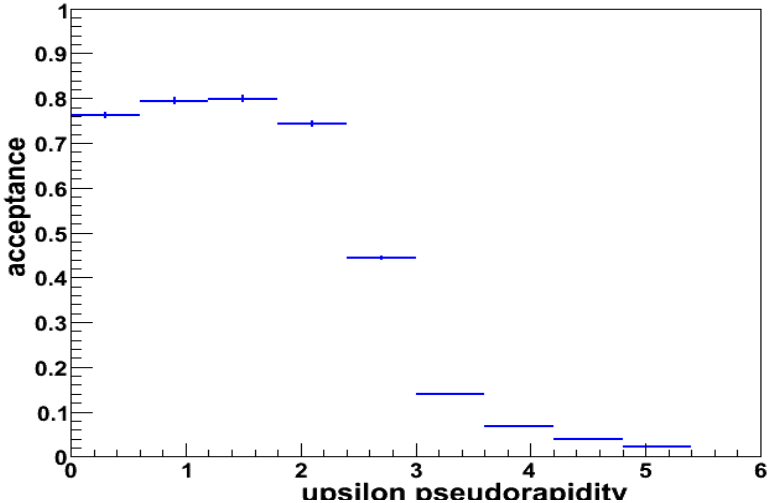


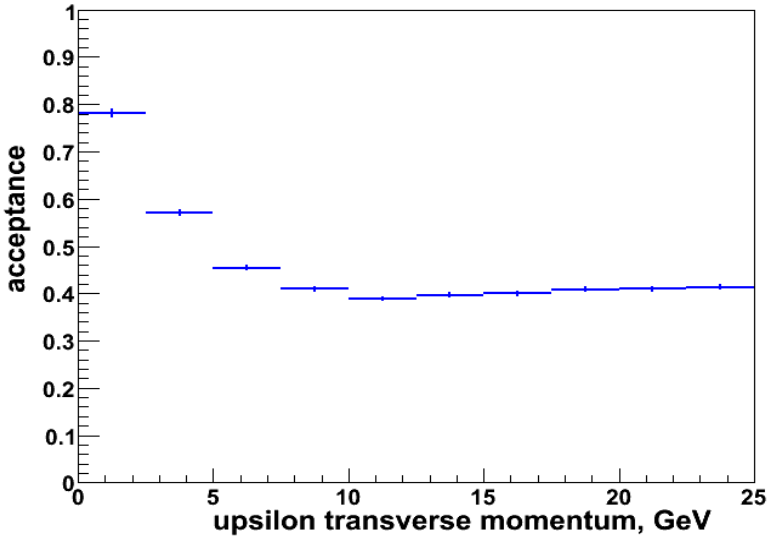
Υ acceptance (singles)

Υ was considered to be in acceptance if both muons produced hits in muon detector.

Projections are done with P_T and η distributions from pythia.



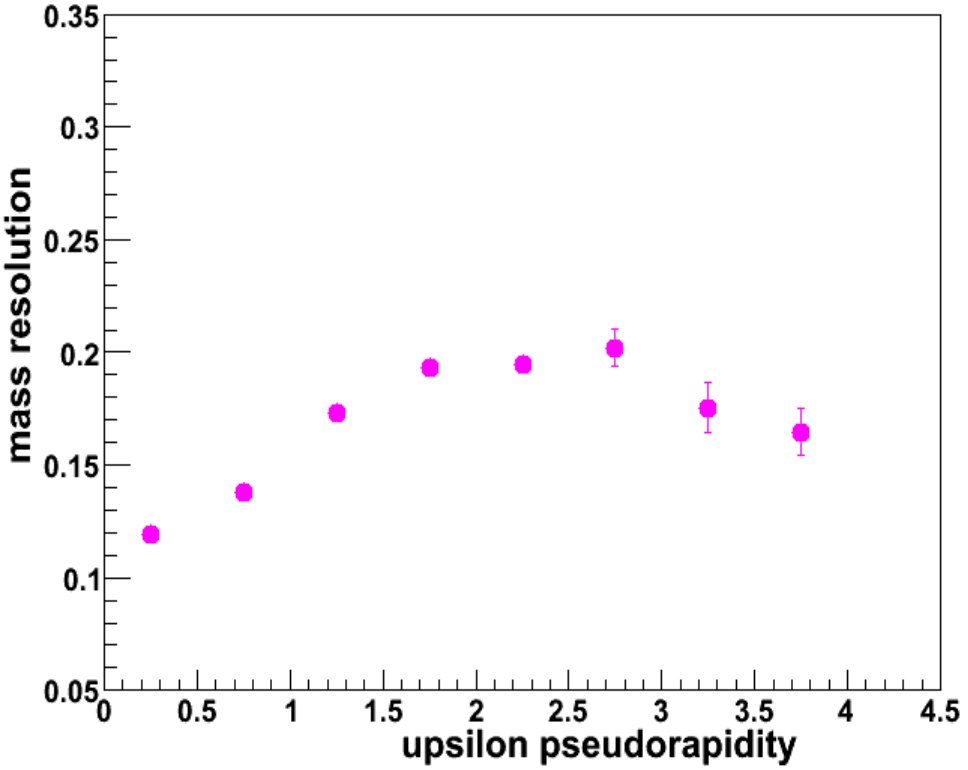


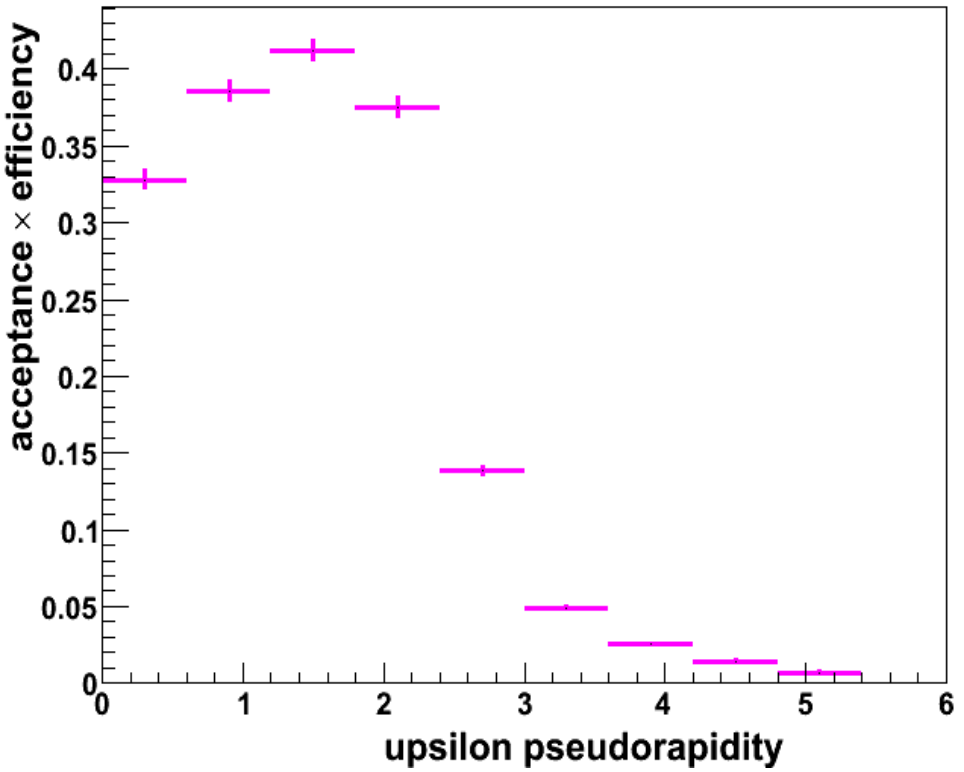


Single Υ (baseline for PbPb)

Integrated (over P_T and η) mass resolution is 177 MeV.

Integrated acceptance times efficiency is ~0.19





Muon triggers

ATLAS Trigger system:

- Level 1 (L1) – configurable hardware

Higher Level Triggers (HLT):

- Level 2 (L2) – software, relies on input from L1
- Event Filter (EF) – off-line algorithms and data model

In PbPb interaction rate is expected to be ~3kHz

Probably no need for L1 trigger for data taking

But need HLT for analysis

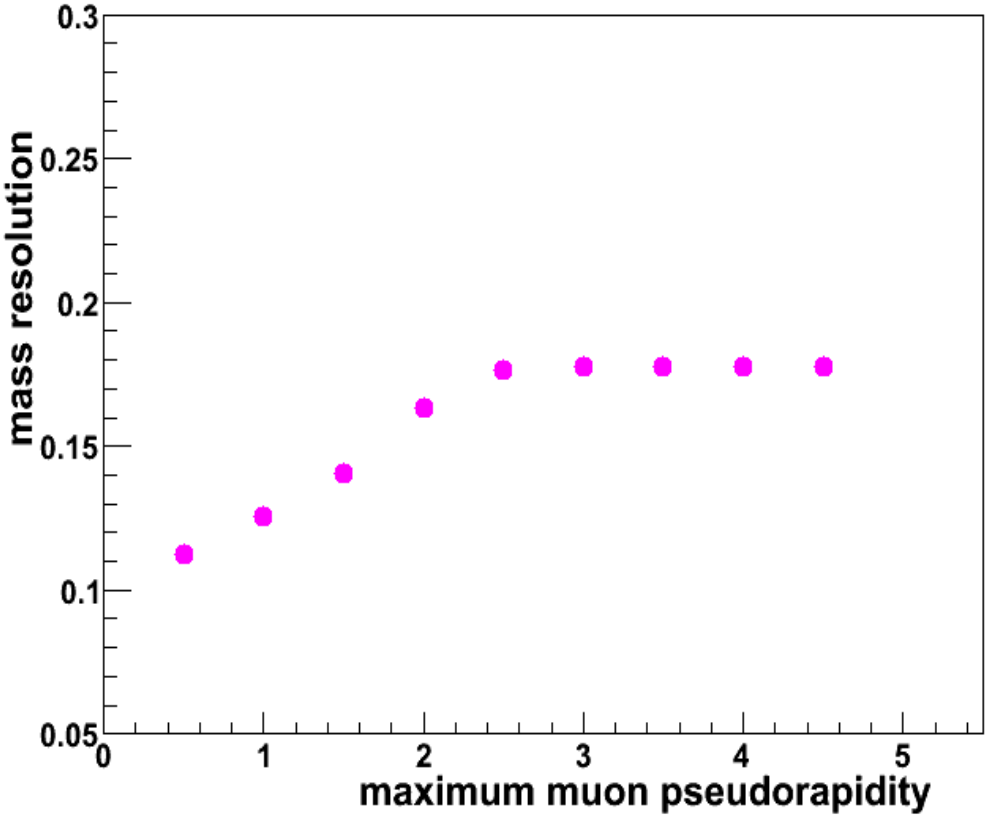
We studied L2 trigger efficiency using merged Upsilon/PbPb events, and fake rate using pure PbPb Hijing events.

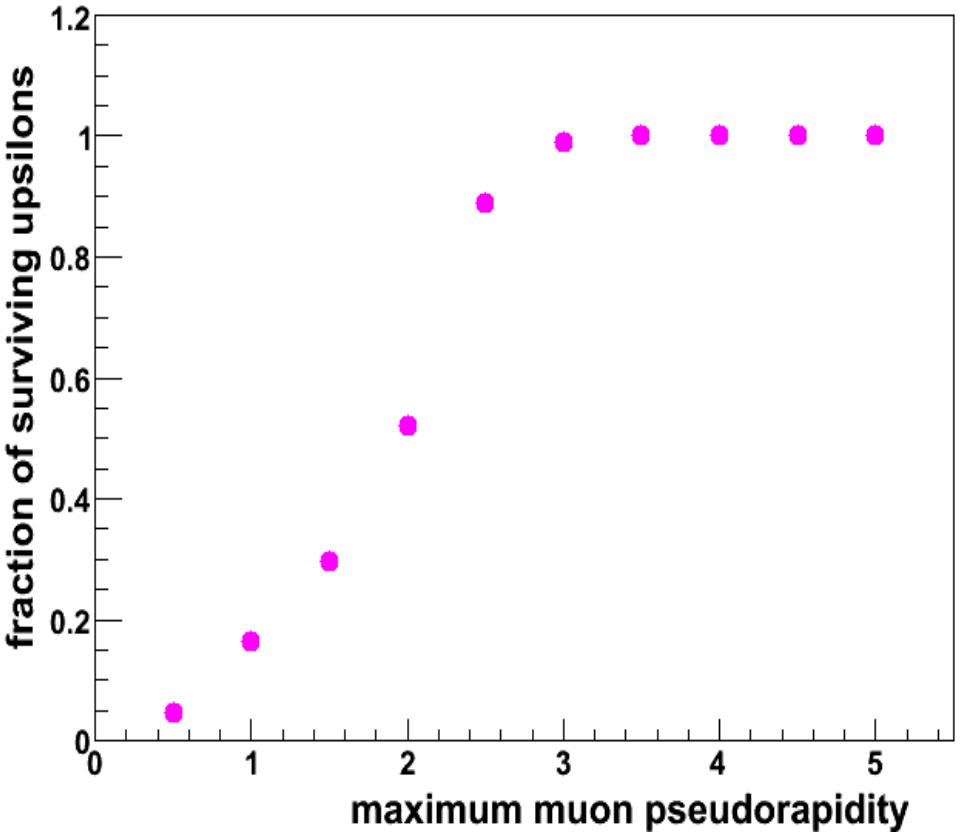
Improving mass resolution

Restrict muon pseudorapidity - but loose statistics.

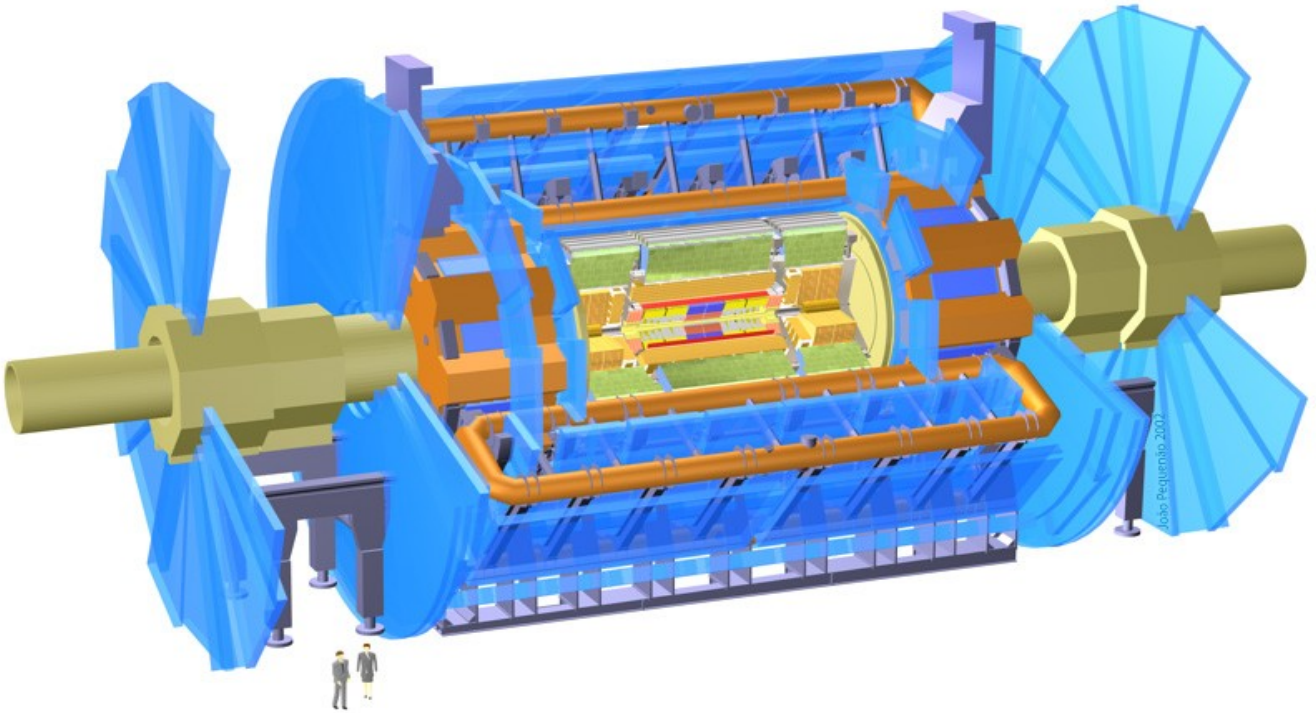
Best mass resolution ~111 MeV (~10% improvement)

Tighter reconstruction cuts can slightly improve this number
- still further loss in statistics





Measuring quarkonia in ATLAS

Quarkonia are measured in di-muon decay channel. ATLAS has excellent muon detection capabilities for $|\eta| < 2.6$ and $P_T > \sim 2.5$ GeV/c

MDT: Monitored drift tubes (barrel and endcaps)
CSC: Cathode strip chambers (endcaps)
RPC: Resistive Plates Chambers (barrel trigger)
TGP: Thin Gap Chambers (endcaps and barrel trigger)